Serial bias in the perception of biological motion emotional states

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People can judge the emotions of other individuals by their movements, which are influenced by previously occurring movements, possibly because previously occurring movements provide a priori information about the current. In the current study, we presented sequences of biological motion of different emotional states and examined the influence of previously occurring actions on the evaluation of emotion for the current action in the biological motion sequence. We found that: first, emotion evaluation for the current biological motion systematically deviated from, rather than bias toward, past evaluation, showing a repulsive bias, with the amplitude of the bias negatively correlated with overall emotion recognition error. Second, the amplitude of the bias was not found to correlate with autistic traits or empathy, but with third-person movement imagery. Results tentatively suggest that there is no attractive bias in biological motion emotion perception, and the repulsive bias produced by previously observed biological motion states on current evaluation is an adaptation-like aftereffect, which enhances the accuracy of emotion recognition, but it is part of general visual cognitive rather than social cognitive functioning.

Keywords: biological motion; adaption; autistic traits; movement imagery

Introduction

Perceiving and evaluating the body movements of others and extracting information from them is an important social cognitive ability (Johnson, 2006). It can help to understand others' emotional states (Bachmann et al., 2020). App et al. (2012) show that both the face and body are important sources of emotion information. A noteworthy issue is, humans always perceive the actions of others in groups, and the perception of an individual action is influenced by the actions of other individuals. For example, Cheng et al. (2022) showed that the perception of an individual's action in a group is biased by the actions of other individuals who are present in the vicinity at the same time. It is important to understand the impact of environments such as these on our social perceptions. Similarly, actions that appear in sequence before may influence the perception of

the current action as well, which exhibits a kind of serial bias. What remains unclear is whether this serial bias exists, and if so, what it is influenced by. The current study was conducted to clarify (1) whether there is serial bias in emotional perception of biological motion and (2) whether it is influenced by social cognitive ability or movement imagery.

Human beings demonstrate great sensitivity to animate movements, which is known as biological motion. Researchers often use point-light displays to simulate biological motion in social cognition experiments (Johansson, 1973). There are large individual differences in biological motion perception sensitivity, Miller and Saygin (2013) showed that sensitivity for biological motion processing was correlated with social cognition (autistic traits, empathy) and movement imagery.

The large majority of research suggested that biological motion perception sensitivity was correlated to autistic traits (e.g. Federici et al., 2019; Puglia & Morris, 2017; van Boxtel et al., 2016). Most of the studies compared biological motion perception between individuals with and without ASD using walking direction recognition or motion naming tasks (Hsiung et al., 2019; Miller & Saygin, 2013; Murphy et al., 2009), while some studies also took emotion-related tasks into account which found that emotion-related tasks can offer better differentiation between different levels of autism traits (Hubert et al., 2007; Foglia et al., 2022), for the poor social skill and empathy of individuals with strong autism traits.

Movement imagery is also an important factor influencing biological motion perception. Human beings actively perceive actions by selecting and running off-line restored sensory-motor memories, by mentally simulating the actions (Savaki & Raos, 2019). Other than that, according to the classical mirror neuron theory, motor imagery

may also be related to mirror neurons which help us to understand other individuals' actions (Rizzolatti & Craighero, 2004). Miller and Saygin (2013) found a correlation between the vividness of motor imagery and the ability to biological motion processing.

Past studies show that, in order to optimize visual processing for stable and efficient encoding of the external environment, past perceptual information needs to be used to process current stimuli, which makes visual information processing biases regularly influenced by history. There is ample evidence that this influence involves early-stage reliance on and later rejection of past perceptions (Fritsche et al., 2020). Attractive bias makes the perception of current stimuli close to past perception to form stable representations (Fischer and Whitney, 2011), which in past studies is called 'serial dependence'. This phenomenon was present in judgments of both simple physical stimuli and social features of faces (Bliss et al., 2017; Fischer and Whitney, 2014; Yu and Ying, 2021). Other than that, there is also repulsive bias, which was considered an adaptation-like aftereffect (Bliss et al., 2017; Webster, 2015). It manifests as the perceptual information for the current stimulus deviates systematically from past perceptions(Clifford et al., 2001). Such mechanisms have been shown to be present in the processing of social features and emotions of facial expressions (Minemoto &Ueda, 2022; Rhodes et al., 2010; Wincenciak et al., 2022). These results above suggest that serial biases may be common principles for the visual system to process both physical and social information. To date, several studies have explored the adaptive aftereffects of walking direction and speed in biological motion (e.g. Theusner et al., 2011; Karaminis et al., 2020), but these studies did not consider the adaptive aftereffects of biological motion in a whole sequence. And no studies have examined the attractive serial bias of biological motion perception.

In the current study, we presented a sequence of biological motions and asked participants to rate them in turn, then fitted the results using the derivative of the Gaussian function. The hypothesis of the current research is divided into the following points. First, considering past results and theories on serial bias, we hypothesized that both attractive and repulsive biases exist in biological motion emotion perception, and the amplitude of bias correlates to recognition error, for serial bias increases the efficiency and stability of visual perception. Second, to explore the factors influencing the serial bias of biological motion emotion recognition, we hypothesized the existence of a correlation between autism traits, empathy, the vividness of movement imagery, and serial bias with reference to past studies on biological motion perception.

Methods

Participants

Forty college students (19 males and 21 females, mean age = 20.37, SD = 1.54 years), with normal or corrected-to-normal vision, participated in this study. We chose 40 as the sample size adapted to previous studies about serial bias and biological motion perception (Bachmann et al., 2020; Hsiung et al., 2019; Yu &Ying, 2021). All participants were naive to the purpose of the experiment and provided informed consent, with ethics approved by the Medical Ethics Committee at Yanbian University.

Self-Report Questionnaires

We adopted the pencil-and-paper questionnaire of the Autism-spectrum Quotient (AQ; Baron-Cohen et al., 2001) which was translated into Chinese by Liu (2008), and the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004) which was translated into

Chinese by Zhao et al.(2018). These two questionnaires measure participants' autistic traits and empathy, respectively, with higher scores representing higher autistic traits and empathy, and they have generally been negatively correlated in past studies. AQ contains five different dimensions: social skills, attention switching, attention to detail, communication, and imagination.

We also administered an assessment of the Vividness of Movement Imagery (VMIQ; Roberts et al., 2008), a measure of movement imagery. The Vividness of Movement Imagery Questionnaire measures three components of motor imagery: visual imagery from a third (external) and first-person (internal) perspective, as well as kinesthetic imagery. A lower score indicates higher motor imagery ability.

Stimuli

We used 50 different front-observed dynamic point-light waker animations created by a web application (https://www.biomotionlab.ca/Experiments/BMLstimuli/index.html) developed by bio motion lab. This tool allows us to reliably adjust the emotional state and body posture of the point-light walker (Troje, 2008). In these animations, 15 dots of light are arranged in a human shape, each representing the movement of a body joint, thus simulating a human walking posture. This type of stimulus material has been widely used in past studies (e.g. Hsiung et al., 2019; Miller & Saygin, 2013). The light spots showing the biological motion are white and are rendered on a black background. We regulate the level of happiness and nervousness of biological motion so that each animation presents different emotions. Meanwhile, to better simulate the real situation, we also adjusted the gender and weight of the walkers in the animation.

Procedure

Before the experiment, each participant's AQ, EQ, and motor imagery were first measured using self-report questionnaires. The general procedure of the experiment was adapted from previous experiments to facilitate comparison with past findings (Miller & Saygin, 2013; Yu &Ying, 2021) (figure 1). A 2-second animation of the point-light walker is shown in each trial, and then participants were asked to rate how happy the walkers are on a Likert scale from 1-7 (1 for most sad and 7 for most happy) on the keyboard. A total of 50 animations, each repeated 4 times, in random order. Before the video starts, a 1-second fixation appears in the center of the screen to alert participants to focus their attention. Text appeared on the screen reminding participants to rate after animations. Participants were asked to respond within 3 seconds if possible, and after 3 seconds the font on the screen would change color to remind participants to make judgments as soon as possible. After scoring 1 second will go to the next trial. We did not restrict the eye movements of the participants throughout the experiment. Before the experiment began, all participants did a brief practice to familiarize themselves with the experimental procedure and form a preliminary judgment of the state of these motions.

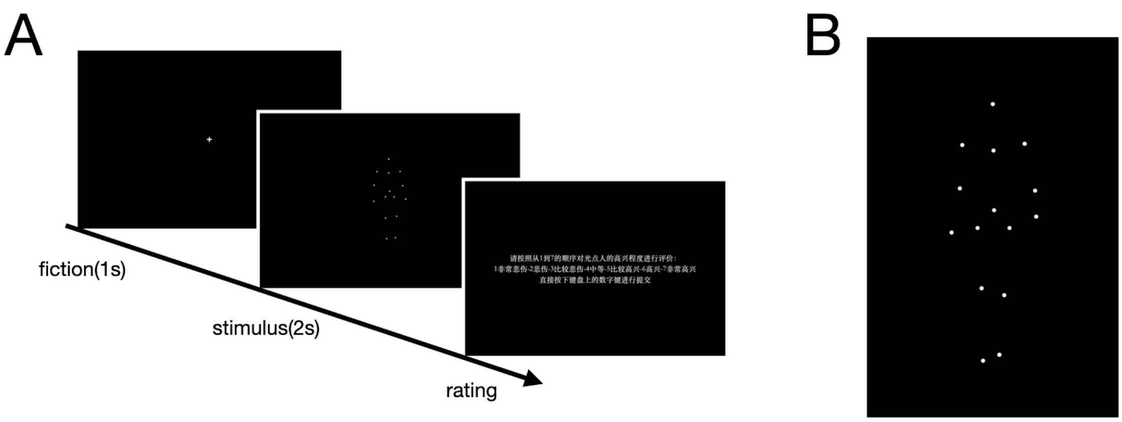

Figure 1. (A) Temporal structure of one trial. (B) An example of a biological motion animation. It's dynamic in actual experiments.

Analytic strategy

General analytic strategy

First, we calculated the average of all participants' ratings of each animation as estimated scores, which represent the general emotion evaluation of most people. The recognition error is operationalized as each participant's actual rating in the current trial minus the estimated score. Ratings that differed from the estimated score by more than 3 *SD*s were replaced by the corresponding estimated score. Each participant's holistic recognition error throughout the experiment was operationalized as the Euclidean distance between the participant's actual scores in all 200 trials and the corresponding 200 estimated scores, reflecting the accumulation of the participant's error in each trial. The amplitude of the serial bias was operationalized as the value of parameter a in the DoG fitting results (see below).

We tested the correlation between serial bias amplitude and AQ, EQ, and movement imagery, then the correlation between recognition error and serial bias amplitude, respectively. In addition to p values, we also report Bayesian factors to compensate for the fact that the NHST is affected by sample size and cannot support the null hypothesis.

DoG fitting

We use the derivative of a Gaussian function (DoG) fitting method to compute the amplitude of the serial bias (Pascucci et al., 2023). We obtained the error of the current trial rating by subtracting the corresponding estimated score from the ratings of individual participants. Subsequently, the experimental results were fitted to DoG using the

"last_squares" function in Python. DoG is defined as $y = \Delta awce^{-(w\Delta)^2}$. y denotes the current trial error that we obtained, Δ indicates the rating difference between the current trial and the n-back trial, a indicates the amplitude of the peak of the curve, w is used to adjust the width of the curve, c is a constant equal to $\sqrt{2}/e - 0.5$. To ensure that we get reasonable parameters, here we restrict w to a range of 0.15 to 5. The amplitude parameter a was taken as the strength of the serial bias, as it indicates how much the current stimulus rating could be biased towards or away from a previous stimulus with the maximally effective difference between stimuli. If the error of the current trial has the same direction as the n-back difference, then $a > 0$, which represents the attractive bias, and conversely $a < 0$ represents the repulsive bias. We obtained the parameter a from 1-back trial to 40-back trial (indicates that the results of the first 40 trials will be excluded).

To assess the significance of a, we will pool the results of all participants, use random numbers in the range of -6 to 6 instead of n-back trial differences to eliminate systematic serial bias, and then refit the DoG and obtain a. This process was repeated 1000 times to produce an artificial null distribution of a. Since we considered both attractive and repulsive biases, a two-sided test was performed, with the p-value being the proportion of the 1000 outcomes with an actual a that was greater (attractive bias) or less (repulsive bias). We set the significance level at 0.05.

Results

We first examined the serial bias in biological motion emotion recognition, analyzed the effect of 1-back to 40-back trials on the current trial, and showed that all 1-back to 40-back trials (each trial took an average of 5.37s) produced significant repulsive bias for the current trial (a range from -1.13 to -0.98, all ps < 0.05), but no attractive bias (figure

2). Since there is only repulsive bias and all *a* are less than 0, in the later analysis, we take the absolute value of *a* as the amplitude of repulsive bias. The larger the absolute value of *a* is, the larger the amplitude of repulsive bias is, which makes the results easier to understand.

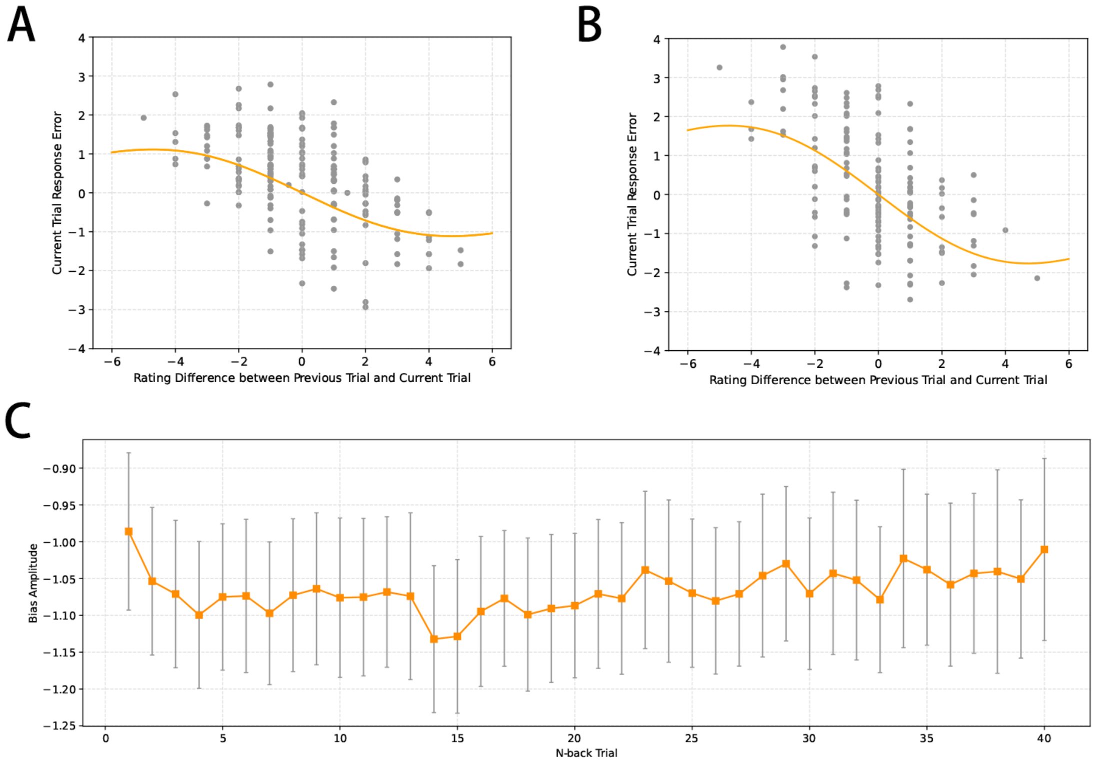

Figure 2. DoG fitting result. (A) To better illustrate our statistical approach, the results of the DoG fit on the 1-back trial for one participant are presented here, *a* = -1.11. The orange curve is the DoG curve, and the gray is the raw data point. The distance from the peak to the valley of the curve represents the amplitude of the bias. (B) DoG fit results on the 40-back trial for this participant, *a* = -1.77. (C) Amplitude of bias from 1-back to 40-back for all participants, gray represents 0.95 confidence interval.

Then, we examined the correlation between the amplitude of repulsive bias and AQ, EQ, and movement imagery. Results showed that the 1-back trial amplitude of repulsive bias was significantly correlated with third-person perspective scores in the VMIQ ($r = 0.35$, $p = 0.02$, $BF_{10} = 2.92$), but not other durations of interval. This sug-

gests that weaker third-person movement imagery is accompanied by greater repulsive bias. And beyond that, no correlation was found between the amplitude of repulsive bias and EQ, AQ, all dimension scores of AQ, and other dimension scores of VMIQ (all *p*s > 0.05, $BF_{10} < 1$).

Finally, we examined the correlation between the amplitude of the 1-back trial repulsive bias and the holistic recognition error. A significant correlation was found between them ($r = -0.34$, $p = 0.03$, $BF_{10} = 2.69$). This suggests that a larger amplitude of repulsive bias is accompanied by a lower recognition error.

Discussion

In this study, we investigated serial biases in the recognition of biological motion emotions. We found that (1) judgments of biological motion emotion systematically deviated from past judgments, showing repulsive bias but not attractive bias, and that the amplitude of repulsive bias was correlated with emotion recognition error, with larger repulsive bias accompanied by lower recognition error. (2) external third-person movement imagery was correlated with the amplitude of repulsive bias. The worse the third-person motor representation ability, the larger the repulsive bias.

The first issue worth noting is that we found no attractive bias. Attractive bias has emerged in a majority of past studies but was not found in our study (Bliss et al., 2017; Fischer & Whitney, 2014; Yu &Ying, 2021). One possible reason is that the main function of the attractive bias is to form object continuity to stimuli that are presented continuously (Fischer and Whitney, 2014). Most past studies have used static stimulus material, which is processed as "frames" in the visual system, while the dynamic picture

used in our experiment is processed as "units". This is an unexpected finding and needs to be considered in future studies.

We found a prolonged repulsive bias in our experiments, which may represent a process of adaptation according to past theories, that is, continuous reconditioning of emotion recognition (Clifford et al., 2001; Webster, 2015). Therefore, not unexpectedly, we found a significant correlation with lower emotion recognition error. This represents that modulation of current perception through past biological motion perception improves the accuracy of emotion recognition. Previous studies have found similar effects on face recognition (Rhodes et al., 2010). But it should be noted that because we used the mean of all participants' ratings of the biological motion emotional state to represent the "correct" rating, this result actually represents a large repulsive aftereffect that brings the rating of individual participants closer to the population average. Since people always deal with many other people at different times of the day, it's important to know how each judgment is affected in such a sequence. There have been similar studies in the past, such as Troje et al. (2006) showing a similar adaptive aftereffect when identifying the gender of others by biological motion.

Another finding was that the amplitude of repulsive bias was not associated with empathy, overall autism traits, and individual autism dimension traits, with Bayesian factors providing evidence in support of the null hypothesis. This may suggest that the amplitude of the repulsive bias is not influenced by social cognitive functioning, but rather by third-person movement imagery. That is adaptation to biological motion emotion is not linked to social cognition but is a general visual cognitive function or perception of movement. The judgment of biological motion emotion may be achieved based on some physical characteristics of the body, such as body swing, walking speed, etc

(Troje, 2008). In our results, poorer third-person movement imagery ability was accompanied by a larger amplitude of bias. It may reflect the compensatory effect of visual adaptation (Webster, 2015). Individuals with weak third-person movement imagery may be more ambiguous in action recognition and therefore need a large degree of recalibration to make their recognition results more accurate.

A drawback of this study is that we found only repulsive bias, but the DoG fitting method is a research tool for attractive bias in the majority of studies. This is because, at the beginning of the study, we considered both attractive and repulsive biases. Although DoG fitting can also provide evidence for adaptation, it is difficult to compare results with past experiments using the visual adaptation paradigm. But one benefit of this approach is that it allows us to analyze the magnitude of adaptation in a continuously presented sequence of biological movements. The preliminary finding in the study is that there is no bias of attraction in the recognition of biological motion emotions. The reason is not clear for the time being, and we speculate on the above. However, it needs to be considered whether this situation is universal or due to our special experimental design. Therefore, the next research plan is to further examine whether there is an attractive bias in biological motion emotion recognition and to revalidate the results of this experiment using the visual adaptation paradigm.

Declaration of Interest Statement

The authors report there are no competing interests to declare.

Data availability statement

The resulting data have been uploaded to the Open Science Framework, DOI:10.17605/OSF.IO/4XCP7.

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